The single-channel Model 2302 Battery Simulator and dual-channel Model 2306 Battery/Charger Simulator were designed specifically for development and test applications of portable, battery-operated products, such as cellular and cordless telephones, mobile radios, and pagers. These precision power supplies have ultrafast transient response so they can have output characteristics identical to actual batteries. These supplies employ a unique variable output resistance so the voltage output can emulate a battery’s response (U.S. Patent No. 6,204,647). They provide stable voltage outputs, even when a device under test (DUT) makes the rapid transition from the standby (low current) state to the RF transmission (high current) state. In addition, they can monitor DUT power consumption by measuring both DC currents and pulse load currents. The Model 2302’s and the Model 2306’s battery-simulator channel can be programmed to operate like a discharged rechargeable battery, sinking current from a separate charger or from the Model 2306’s charger-simulator channel.

Maximize Test Throughput with Accurate Battery Simulation

The battery-output channels of the Models 2302 and 2306 are designed to simulate the output response of a battery. This capability, combined with their fast transient response, makes it possible to power the device during testing in exactly the same way as a battery will power the device during actual use. The output resistance of the Model 2302’s and the Model 2306’s battery channel can be programmed (with 10Ω resolution) over the range from 0Ω to 1Ω so that the output resistance can be set to the same level as the output resistance of the battery that powers the device. See Figure 1.

Portable wireless devices make great demands on their battery power sources. The battery must source load currents that can jump virtually instantaneously from a standby current level (100–300mA) to a full-power RF transmission current level (1–3A). In other words, the load current on the battery can increase rapidly by a factor of 700–1000%. As a result, the battery voltage drops by an amount equal to the value of the current change multiplied by the battery’s internal resistance. The Models 2302 and 2306 power supplies enable test systems to duplicate this voltage drop by programming their output resistance to be equivalent to that of the battery that will power the device. This allows wireless device manufacturers to test their products under the same power conditions that they will encounter in actual use. (See Figure 2.)

Figure 1. Simplified schematic of a battery and the 2302/2306.

ACCESSORIES AVAILABLE

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• Ultrafast response to transient load currents
• Choice of single- or dual-channel supplies
• Optimized for development and testing of battery-powered devices
• Variable output resistance for simulating battery response (U.S. Patent No. 6,204,647)
• Pulse peak, average, and baseline current measurements
• 100nA DC current sensitivity
• Current step measure function
• Sink up to 3A
• Open sense lead detection
• Built-in digital voltmeter

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In response to large load changes, the Model 2302 and the battery channel of the Model 2306 have transient voltage droops of less than 100mV and transient recovery times of less than 60µs, even when the test leads between the power supply and the DUT are long. This fast transient response, combined with the supplies’ variable output resistance, allows engineers to test their portable products under the most realistic operating conditions and eliminate false failures due to conventional power supplies with slow response times. (See the sidebar titled “Conventional Power Supplies and Wireless Device Testing.”) These supplies also eliminate the large stabilizing capacitors needed at the DUT to compensate for the large droop that occurs when testing with conventional power supplies. By varying the output resistance, which can be done while the output is turned on, test engineers can simulate the operation of different battery types, as well as batteries nearing the end of their useful lives.

The Models 2302 and 2306 ensure maximum production throughput when testing portable devices by minimizing false failures, minimizing the number of test setups by performing multiple tests with the same power supply, and minimizing test fixture complexity by eliminating the need for voltage-stabilizing capacitors.

**Figure 2.** Comparison of the voltage outputs of a lithium-ion battery (with an internal resistance of 260mΩ) and the Model 2306’s battery channel (programmed with an output resistance of 260mΩ) when powering a cellular telephone as it makes the transition from standby mode to transmit mode.

**Figure 3.** Built-in pulse current measurement functions allow test engineers to measure peak, average, and baseline load currents.
Measure Long-Period Waveform Currents
For pulse trains with periods longer than 850ms, the Models 2302 and 2306 offer a unique, long integration current measurement mode. This mode can provide an average measurement of a current waveform from 850ms up to 60 seconds long.

Measure Low Currents Accurately
The Models 2302 and 2306 are based on Keithley's expertise in low current measurement technologies, so they're well-suited for making fast, accurate measurements of sleep and standby mode currents. With 100nA resolution and 0.2% basic accuracy, they provide the precision needed to monitor the low sleep mode currents of both today's battery-operated products and tomorrow's.

Verify Load Currents in All Operating States
The Models 2302 and 2306 employ a unique pulse current step function for measuring the load current at each level of a device's operational states. (See Figure 4.) For example, if a cellular phone is ramped up and down through as many as 20 discrete power consumption states, the Models 2302 and 2306 can measure the load currents in synchronization with the current steps. This capability allows a test engineer to verify performance at each operational state and simultaneously acquire power consumption information. The fast current measure capability is another way the Models 2302 and 2306 power supplies save test time and production costs.

Simulate a Discharged Battery for Charger Testing
The Models 2302 and 2306 can sink up to 3A continuously, just like an electronic load. This allows these supplies to simulate a discharged rechargeable battery for use in testing the performance of battery chargers or battery charger control circuitry.

The Model 2306 Battery/Charger Simulator combines the functionality of both the charging current source (the charger channel) and the current sinking to simulate the recharging of a discharged battery (the battery channel) in a single enclosure. (See Figure 5.)

Open-Sense Lead Detection
The Model 2302 and 2306 have an automatic open-sense lead detection capability, which indicates if there is a broken remote sense lead or an open connection from a remote sense lead to the test fixture. To ensure
Big Functionality in a Small Package

For high volume production environments where floor and test rack space are at a premium, the Model 2306 packs two power supplies into one half-rack enclosure. In addition to power control, both the Model 2302 and 2306 provide extensive measurement capabilities in the same half-rack case. The front panel of each unit displays the user’s choice of either the output voltage and output current, the average, peak, and baseline pulse current levels, long integration currents, or DC DVM measurements. A minimum of front panel buttons ensures that operation is simple and straightforward.

For additional control requirements, the Models 2302 and 2306 each have four digital relay control outputs and a 5V DC output to power a relay coil.

Remote Display Option

If the Model 2302, 2306, or 2306-PJ must be mounted in a location in which the front panel display is not readily visible, an optional Model 2306-DISP Display Module can be mounted at a more convenient point, then plugged into the power supply unit. The display module also includes all instrument controls, so that the power supply can be operated remotely from the more accessible location. See Figure 7.

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Figure 7. Optional Model 2306-DISP Display Module

Figure 8. Model 2306 Rear Panel showing 8-position power output connectors, RJ-45 remote display connector, DB-9 relay output connector, IEEE-488 connector, and power input socket.
2302
2306, 2306-PJ

Battery Simulator
Battery/Charger Simulators

**OUTPUT #1 (BATTERY)**

**DC VOLTAGE OUTPUT (2 Years, 23°C ± 5°C)**
- **OUTPUT VOLTAGE:** 0 to +15V DC
- **OUTPUT ACCURACY:** ±(0.05% + 3mV)
- **PROGRAMMING RESOLUTION:** 1mV
- **READBACK ACCURACY:** ±(0.05% + 3mV)
- **MEASUREMENT TIME CHOICES:** 0.01 to 10PLC7, in 0.01PLC steps
- **MEASUREMENT TIME6:** Available on 5A and 500mA ranges.

**CONTINUOUS AVERAGE OUTPUT CURRENT (2302):**
- 0–50A max
- 3A max

**CONTINUOUS AVERAGE OUTPUT CURRENT (2306):**
- Channel #2 (Charger) OFF:
  - Available current = 100W – Power consumed by channel #2 (sink current)
  - Power consumed = (VSET channel 2 + 6V) × (current supplied)
- Channel #2 (Charger) ON:
  - Available current = (50W – Power consumed by channel #2)/5; 3A max.
  - Derate 0.2A per volt above 5V.

**VARIABLE OUTPUT IMPEDANCE**
- **RANGE:** 0 to 1.00Ω in 0.01Ω steps. Value can be changed with output on.

**DC CURRENT (2 Years, 23°C ± 5°C)**
- **CONTINUOUS AVERAGE SINK CURRENT (2302):**
  - 0–5A max
- 3A max
- 5–15V: Derate 0.2A per volt above 5V.
- Derate 0.2A per volt above 5V

**SOURCE COMPLIANCE ACCURACY:** ±(0.01% + 5mA)

**PROGRAMMED SOURCE COMPLIANCE RESOLUTION:** ±(0.1% + 50µA)

**READBACK RESOLUTION:** ±(0.05% + 20µA)

**LOAD REGULATION:** ±(0.2% + 20µA)

**LINE REGULATION:** ±(0.2% + 20µA)

**STABILITY:** ±(0.05% + 50µA)

**MEASUREMENT TIME CHOICES:** 0.01 to 10PLC7, in 0.01PLC steps

**MEASUREMENT TIME6:** Available on 5A range.

**BURST MODE CURRENT MEASUREMENT**
- **MEASUREMENT APERTURE:** 33.3µs
- **CONVERSION RATE:** 3600 samples/second, typical
- **INTERNAL TRIGGER DELAY:** 15µs
- **NUMBER OF SAMPLES:** 1 to 5000
- **TRANSFER SAMPLES ACROSS IEEE BUS IN BINARY MODE:** 4800 bytes/s, typical

**LONG INTEGRATION MODE CURRENT MEASUREMENT**
- **MEASUREMENT TIME:** 850ms (840ms) to 60 seconds in 1ms steps

**DIGITAL VOLTMETER INPUT (2 Years, 23°C ± 5°C)**
- **INPUT VOLTAGE RANGE:** -5 to +30V DC
- **INPUT IMPEDANCE:** 2MΩ
- **MAXIMUM VOLTAGE (either input terminal) WITH RESPECT TO OUTPUT LOW:** -5V +30V
- **MEASUREMENT TIME:** Maximum: 850ms (840ms) to 60 seconds in 1ms steps.
- **CONNECTION:** HI and LO input pair part of Output #1’s terminal block.

**PULSE CURRENT MEASUREMENT OPERATION**
- **TRIGGER LEVEL:**
  - 5A CURRENT RANGE
  - 5mA to 5A in 5mA steps
  - 1A Range:
  - 1mA to 1A in 1mA steps
  - 100mA Range:
  - 0.1mA to 100mA in 100µA steps
  - 500mA CURRENT RANGE (2306-PJ):
  - 5mA to 500mA in 5mA steps
  - 100mA Range:
  - 0.1mA to 100mA in 100µA steps
  - 10mA Range:
  - 100µA to 10mA in 100µA steps
- **INTERNAL TRIGGER DELAY:** 15µs

**PULSE CURRENT MEASUREMENT ACCURACY**
- **APERTURE:**
  - <100µs: ±0.2% + 900µA + 2mA
  - 100µs to 200µs: ±0.2% + 900µA + 1.5mA
  - 200µs to 500µs: ±0.2% + 900µA + 1mA
  - 500µs to 1 PLC: ±0.2% + 800µA + 0.8mA
  - 1 PLC: ±0.2% + 400µA + 0mA
  - >1 PLC: ±0.2% + 400µA + 100µA

**BATTERY SIMULATOR**
- **Model 2302, 2306, 2306-PJ specifications**
- **Battery/Charger Simulators**
- **DC CURRENT (2 Years, 23°C ± 5°C)**
- **CONTINUOUS AVERAGE SINK CURRENT (2302):**
  - 0–5A max
  - 3A max
  - 5–15V: Derate 0.2A per volt above 5V

**SOURCE COMPLIANCE ACCURACY:** ±(0.01% + 5mA)

**PROGRAMMED SOURCE COMPLIANCE RESOLUTION:** ±(0.1% + 20µA)

**READBACK RESOLUTION:** ±(0.05% + 20µA)

**LOAD REGULATION:** ±(0.2% + 20µA)

**LINE REGULATION:** ±(0.2% + 20µA)

**STABILITY:** ±(0.05% + 50µA)

**MEASUREMENT TIME CHOICES:** 0.01 to 10PLC7, in 0.01PLC steps

**MEASUREMENT TIME6:** Available on 5A range.

**MAXIMUM VOLTAGE (either input terminal) WITH RESPECT TO OUTPUT LOW:** -5V +30V

**MEASUREMENT TIME:** 850ms (840ms) to 60 seconds in 1ms steps.

**CONNECTION:** HI and LO input pair part of Output #1’s terminal block.

**MEASUREMENT TIME6:** Available on 5A range.

**BURST MODE CURRENT MEASUREMENT**
- **MEASUREMENT APERTURE:** 33.3µs
- **CONVERSION RATE:** 3600 samples/second, typical
- **INTERNAL TRIGGER DELAY:** 15µs
- **NUMBER OF SAMPLES:** 1 to 5000
- **TRANSFER SAMPLES ACROSS IEEE BUS IN BINARY MODE:** 4800 bytes/s, typical

**LONG INTEGRATION MODE CURRENT MEASUREMENT**
- **MEASUREMENT TIME:** 850ms (840ms) to 60 seconds in 1ms steps

**DIGITAL VOLTMETER INPUT (2 Years, 23°C ± 5°C)**
- **INPUT VOLTAGE RANGE:** -5 to +30V DC
- **INPUT IMPEDANCE:** 2MΩ
- **MAXIMUM VOLTAGE (either input terminal) WITH RESPECT TO OUTPUT LOW:** -5V +30V
- **MEASUREMENT TIME:** Maximum: 850ms (840ms) to 60 seconds in 1ms steps.
- **CONNECTION:** HI and LO input pair part of Output #1’s terminal block.

**MEASUREMENT TIME6:** Available on 5A range.

**BURST MODE CURRENT MEASUREMENT**
- **MEASUREMENT APERTURE:** 33.3µs
- **CONVERSION RATE:** 3600 samples/second, typical
- **INTERNAL TRIGGER DELAY:** 15µs
- **NUMBER OF SAMPLES:** 1 to 5000
- **TRANSFER SAMPLES ACROSS IEEE BUS IN BINARY MODE:** 4800 bytes/s, typical

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2302, 2306, 2306-PJ Specifications

**Battery Simulator**

**Battery/Charger Simulators**

**OUTPUT #2 (CHARGER)**

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**DC VOLTAGE OUTPUT (2 Years, 23°C ± 5°C)**

- **OUTPUT VOLTAGE:** 0 to +15V DC.
- **OUTPUT ACCURACY:** ±(0.05% + 10mV).
- **PROGRAMMING RESOLUTION:** 0.1mV.
- **READBACK ACCURACY:** ±(0.05% + 3mV).
- **LINE REGULATION:** 0.5mV.
- **STABILITY:** 0.01% + 0.5mV.

**SOURCE COMPLIANCE ACCURACY:**

- **±(0.16% + 5mA).**

**CONTINUOUS AVERAGE SINK CURRENT:**

- **Peak currents can be a maximum of 5A provided the average current is within the above limits.**

**LOAD REGULATION:** 0.01% + 2mV.

**MEASUREMENT TIME CHOICES:** 0.01 to 10PLC, in 0.01PLC steps.

**TRANSIENT RESPONSE:**

- **High Bandwidth:** <50µs² or <800µs³
- **Low Bandwidth:** <600µs² or <1000µs³

**OUTPUT VOLTAGE SETTLING TIME:**

- 5ms to within stated accuracy.

**STABILITY:**

- **±(0.2% + 200µA).**

**MEASUREMENT TIME CHOICES:** 0.01 to 10PLC, in 0.01PLC steps.

**ARENA READINGS:** 1 to 10.

**READING TIME:** 31ms, typical.

**REMOTE SENSE:**

- 1mV.

**TRANSIENT VOLTAGE DROP:**

- <120mV or <150mV.

**TRANSIENT RECOVERY TIME:**

- <50µs or <80µs.

**INPUT IMPEDANCE:**

- 500Ω – <1 PLC 0.2% + 600µA + 0.8mA
- 100µs – 200µs 0.2% + 900µA + 1.5mA
- 200µs – 500µs 0.2% + 900µA + 1mA
- <1 PLC 0.2% + 400µA + 0.8mA

**SOURCE COMPLIANCE ACCURACY:** ±(0.05% + 10mV).

**PROGRAMMED SOURCE COMPLIANCE RESOLUTION:** 1.25mA.

**READBACK ACCURACY:**

- **0.5A Range:** ±(0.16% + 5mA).
- **5A Range:** ±(0.02% + 200µA).
- **10A Range:** ±(0.02% + 1µA).

**BURST RATE:**

- **Continuous:** 1 to 100.
- **Peak:** 1 to 10.

**DC CURRENT (2 Years, 23°C ± 5°C) CONTINUOUS AVERAGE OUTPUT CURRENT:**

- **Channel #1 (Battery) OFF:**
  - 1 = 500V, channel 2 = 6V; 5A max.
  - 1 = 150W - Power consumed by channel #1/Vcc, channel 2 = 6V; 5A max.
  - The power consumed by channel #1 is calculated as:
    - **Channel #1 sourcing current:**
      - Power consumed = (Vcc, channel 1 + 6V) × (current supplied)
    - **Channel #1 sinking current:**
      - Power consumed = 5 × (sink current)

**MEASUREMENT TIME CHOICES:** 0.01 to 10PLC, in 0.01PLC steps.

**MEASUREMENT APERTURE SETTINGS:**

- **HIGH/LOW:±(0.05% + 3mV).**
- **AVERAGE:** ±(0.05% + 1µA).

**CONVERSION RATE:**

- 2040/second, typical.
- 4800 bytes/s, typical.

**LONG INTEGRATION MODE CURRENT MEASUREMENT:**

- MEASUREMENT TIME: 850ms (840ms) to 60 seconds in 1ms steps.

**DIGITAL VOLTMETER INPUT (2 Years, 23°C ± 5°C)**

- **INPUT VOLTAGE RANGE:** -5 to +30V DC.
- **INPUT IMPEDANCE:** 2MΩ typical.
- **MEASUREMENT TIME:**
  - 60Hz (50Hz).
- **MEASUREMENT TIME (**HIGH/LOW/AVERAGE**): 33.3µs.

**TRANSFER SAMPLES ACROSS IEEE BUS IN BINARY MODE:**

- 4800 bytes/s, typical.

---

1. MAXIMUM VOLTAGE (either input terminal) WITH RESPECT TO OUTPUT LOW - 5V + 30V
2. INTERNAL TRIGGER DELAY: 10µs.
3. INTERNAL TRIGGER DELAY: 15µs.
4. 1PLC = Power Line Cycle. 1PLC = 16.7ms for 60Hz operation, 20ms for 50Hz operation.
5. Minimum current in constant current mode is 6mA.
6. 60Hz (50Hz).
7. PLC = Power Line Cycle. 1PLC = 16.7ms for 60Hz operation, 20ms for 50Hz operation.
8. Display off.
9. Speed includes measurement and binary data transfer out of GPIB.
10. Typical values, peak-to-peak noise equals 6 times rms noise.
11. Based on settled signal: 100µs pulse trigger delay.
12. Also applies to other apertures that are integer multiples of 1PLC.
13. Recovery to within 20mV of previous level.

---

**PULSE CURRENT MEASUREMENT OPERATION**

- **TRIGGER LEVEL:** 5mA to 5A, in 5mA steps.
- **TRIGGER DELAY:** 0 to 100ms, in 10µs steps.
- **INTERNAL TRIGGER DELAY:** 15µs.
- **HIGH/LOW/AVERAGE MODE:** 33.3µs to 833ms, in 33.3µs steps.
- **Average Readings:** 1 to 100.

**PULSE CURRENT MEASUREMENT ACCURACY:**

- **APERTURE**
  - <100 µs: 0.2% + 900 µA + 2 mA
  - 100 µs - 200 µs: 0.2% + 900 µA + 1.5mA
  - 200 µs - 500 µs: 0.2% + 900 µA + 1 mA
  - 500 µs - <1 PLC: 0.2% + 600 µA + 0.8mA
  - 1 PLC: 0.2% + 400 µA + 0 mA
  - >1 PLC: 0.2% + 400 µA + 100µA

**BURST MODE CURRENT MEASUREMENT**

- **MEASUREMENT APERTURE:** 33.3µs.
- **MEASUREMENT TIME:**
  - 850ms (840ms) to 60 seconds in 1ms steps.

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